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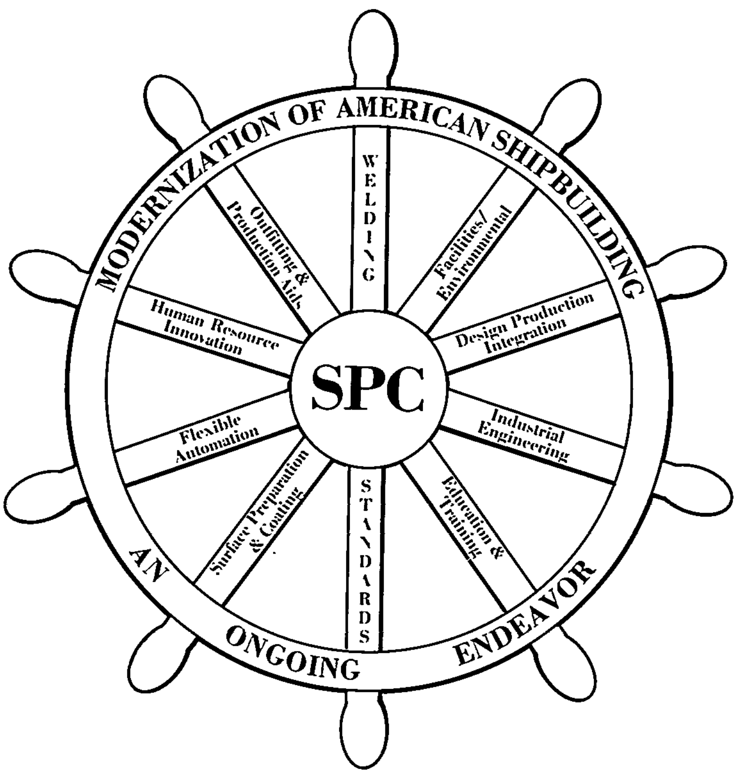

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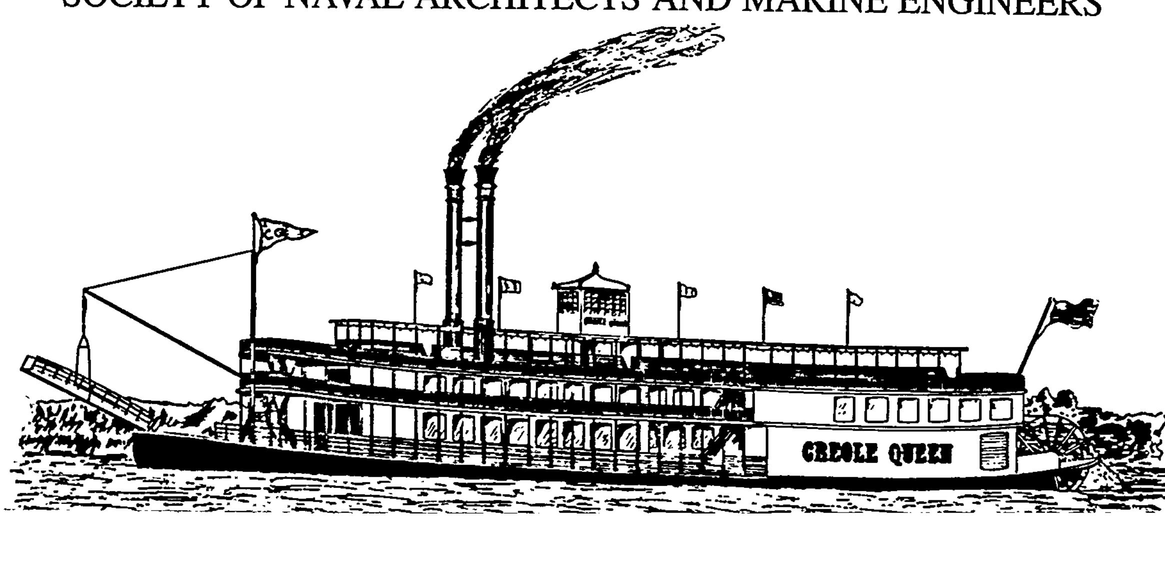

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Computer Aided Process Planning—A Path to Just-in-Time Manufacturing for Shipyards

No. 14

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ABSTRACT

The use of computers to improve the productivity of U.S. shipyards has never been as successful as hoped for by the designers. Many applications were simply the conversion of an existing process to a computerized process.

The manufacturing data base required for the successful application of Computer Aided Process Planning (CAPP) to the shipyard environment requires a "back to basics" approach. An approach that can lead to control of the processes occurring in the fabrication and assembly shops of a shipyard. The manufacturing data base will not provide management feedback designed for the financial segment of the shipyard (although it can be converted to be fully applicable) it provides "real time" manufacturing data that the shop floor manager can utilize in his day to day decisions - not historical data on how his shop did last week or last month.

The computer is only a tool to be used to organize the mountains of manufacturing data into useful information for today's shop manager on a "real time" basis. The use of group technology to collect similar products, the use of parameters to clearly identify work content, the use of real time efficiency rates to project capacity and realistic schedules and the use of bar codes to input "real time" data are all tools that are part of the process. Tools for the shop floor manager of tomorrow.

INTRODUCTION

"Just-in-time" manufacturing for U.S. Shipyards is considered by many to be an impossible goal. Computer Aided Process Planning can change that into reality for many areas in the shipyard. It does require that engineers utilize group technology to identify similar interim products, planners gather better work content information based on parameters, schedulers develop and use "real time" efficiency rate information, shop managers establish process lanes to produce similar interim products using standard processes, and cost administrators gather data based on the processes occurring in each process lane. Yes, interim products, group technology, work content, parameters, efficiency rates and process lanes are new terms that today's shipyard managers must become familiar with. However, the technologies associated with these new terms are not new. They utilize concepts developed in the 1930's such as "group technology". Drawings of similar interim products resemble the drawings used during the "stick built" era of shipbuilding. Parameters and efficiency rates result from the utilization of the basic building blocks of which shipbuilding has been composed. It is a "back to basics" exercise to get control of the activities occurring in the shipyard: the application of old technologies such as statistical quality control and new technologies such as personal computers to improve the efficiency of the shipbuilding process, and to achieve "Just-in-time" manufacturing in the U.S. Shipbuilding Industry.

INTERIM PRODUCT/CONSTRUCTION PROCESS DEFINITION

The implementation of Computer Aided Process Planning (CAPP) requires that the following factors be established in the manufacturing environment:

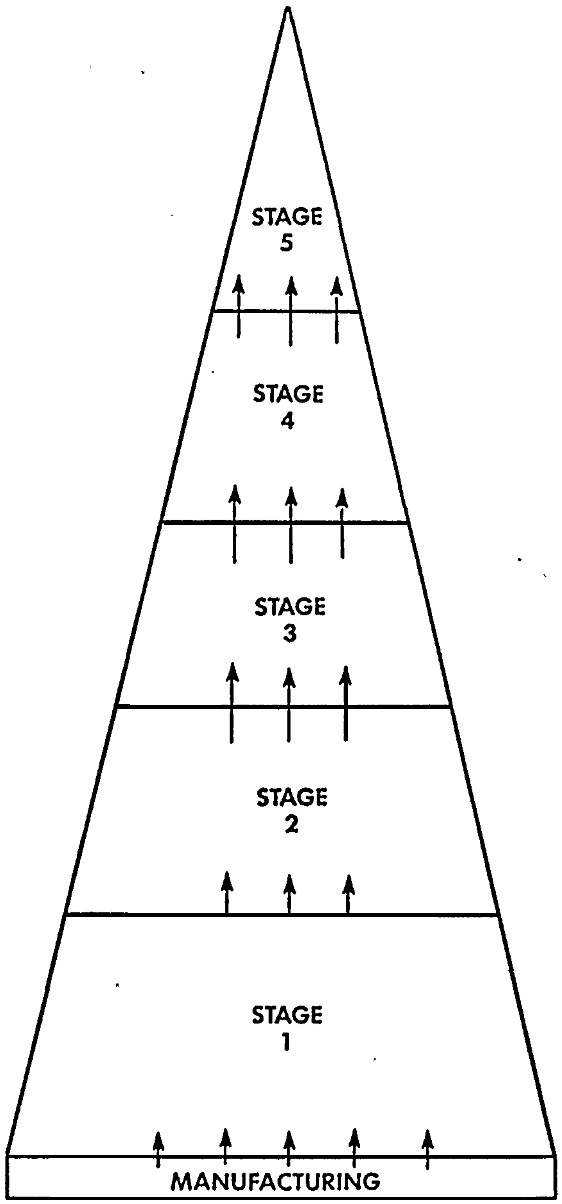
- o A consistent vocabulary
- o A clear identification of processes
- o A clear identification of products
- o A simple work content measurement tool
- o A measurable definition of shop process lane capacity.

A lack of understanding of these factors could cause the majority of U.S. shipbuilders to believe that automated process planning can only be applied to multiple ship construction programs and perhaps then only to a limited extent where unit similarity and series production can be applied. This opinion is reinforced through constraints imposed by the layout of fabrication shops and through the macro-level view of shipbuilding processes which obscures product/process similarities that exist on the micro-level. Consequently, the implementation of any automated process planning system in a shipyard environment must be preceded by the development of a model that addresses each of these factors and by a training program which explains the model and the logic used to develop it. Once the model is developed, the manufacturing data can be quantified, training can occur and automated process planning can be implemented in the shipbuilding industry. This has already been done in many machine shop-type industries, such as cylindrical shaft and gear manufacturers.

Frank Logan, in his paper "The Five Stages to Automated Process Planning," describes the stages of process .planning using a triangle with manufacturing data as the base upon to which build the manufacturing processes. (see Figure 1). During the initial development of CAPP for shipyards it was discovered that the only type of shop which had repeatable manufacturing data available was the machine shop where the majority of time is expended in machine operations. Machine shops also benefit from the significant amount of work which has been done to develop set-up time parameters. Consequently, the majority of existing CAPP systems are designed for machine shop applications. The U.S. Army Missile Command System, CMPP, is an example of such a system.

Existing machine shop CAPP systems organize the manufacturing data in a logical, structured manner which is easily related to the design, planning, budgeting and scheduling processes. Figure 2 illustrates the basic concept. Classification of individual parts into families of parts with similar attributes early in the design process is a key element of a philosophy developed in the 1930's known as Group Technology (GT). In the "stick building" era of shipbuilding, GT concepts were applied in shipyards as similar interim products were grouped on separate drawings, such as web frames, stiffeners, and shell plates. Similar materials were consequently grouped on each drawing and the assembly process followed a similar, logical pattern using each of the drawings in each stage of construction. With the advent of unit construction, the assembler was forced to deal with all of the drawings at one time since each unit was only a small part of each drawing. The evolution continued and the unit drawing was developed to support the assembly shop personnel. In order to facilitate material control, raw materials were also grouped by unit. This resulted in small pieces of raw material having to be handled by fabrication shops to support the unit assembly process. Unfortunately this has also resulted in the groupings of fabricated items by unit with the result that there are only one or a few in each unit. This naturally reduced efficiencies in the structural fabrication shop and in most of the other fabrication shops as well. CAPP and its inherent requirement to organize manufacturing data in a logical, structured manner can have the effect of bringing the shipbuilding industry full circle. Fabrication shops will once again see World War II type drawings for groups of similar interim products with the added dimension of organizing such drawings based on a schedule window added to achieve "just-in-time" manufacturing.

The recognition of the interim product similarities allows the fabrication shop to group such interim products and fabricate them using a process lanes approach. The resulting repetition of similar work provides learning curve savings. In addition, the processes for each process lane remain relatively constant and the processes can be analyzed for productivity improvement through the use of



AUTOMATIC PROCESS PLANNING DRIVEN BY COMPLEX PART CODING AND MANUFACTURING LOGIC DECODING CAPABILITIES WITH LINKS TO CAD.

SEMI-AUTOMATIC PROCESS PLANNING DRIVEN BY SIMPLE CODING SYSTEMS WITH MANUAL ENTRY OF SOME DATA, E.G., DIMENSIONS.

FEATURE (ATTRIBUTE) DRIVE PROCESS PLANNING FROM GROUPS KEYWORDS AND SIMPLE AUTOMATIC SELECTION OF BASE PARAMETERS.

ENTRY LEVEL INTERACTIVE COMPUTER-AIDED TIME ESTIMATING AND METHODS PLANNING USING QUESTIONS AND/OR PARAMETER DRIVEN MANUFACTURING LOGIC WHICH HAS DIRECT ACCESS TO TIME/COST STANDARD DATABASE.

TRADITIONAL MANUAL PROCESS PLANNING USING PERSONAL EXPERIENCE TO DERIVE MANUFACTURING LOGIC AND EXTRACT TIME/COST STANDARD DATA AND WRITE OUT MANUFACTURING INFORMATION.

FIG . 1 THE FIVE STAGES OF PROCESS PLANNING

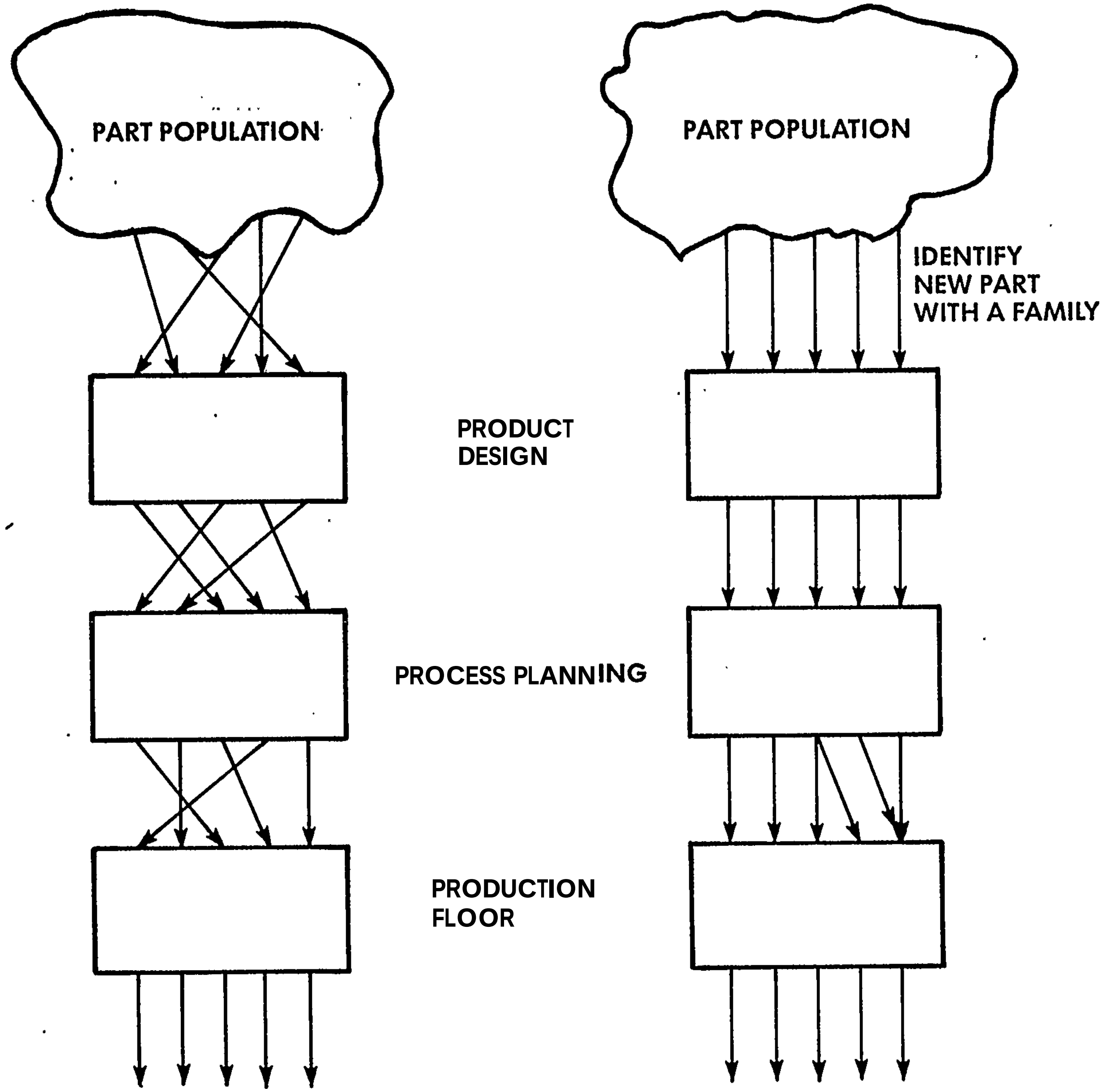


FIG. 2 STRUCTURED MANUFACTURING DATA

jigs and fixtures and/or new or improved technologies. Statistical analysis can also be applied to determine the trends in quality and productivity as well as monitoring the effect of jigs and fixtures and/or new technologies that may have been implemented.

Product/Process Matrix Logic

The National Shipbuilding Research Program publication, "Product Work Breakdown Structure", June 1986, has provided a useful organizational tool for analyzing the shipbuilding process. It subdivides a ship into manageable subsets of interim products.

These interim products can be grouped into families that require similar manufacturing processes. These families of products can further be grouped by the shop or trade that has responsibility for their manufacture. This product/process information for the fabricating trades/shops is presented in a matrix format in Figure 3:

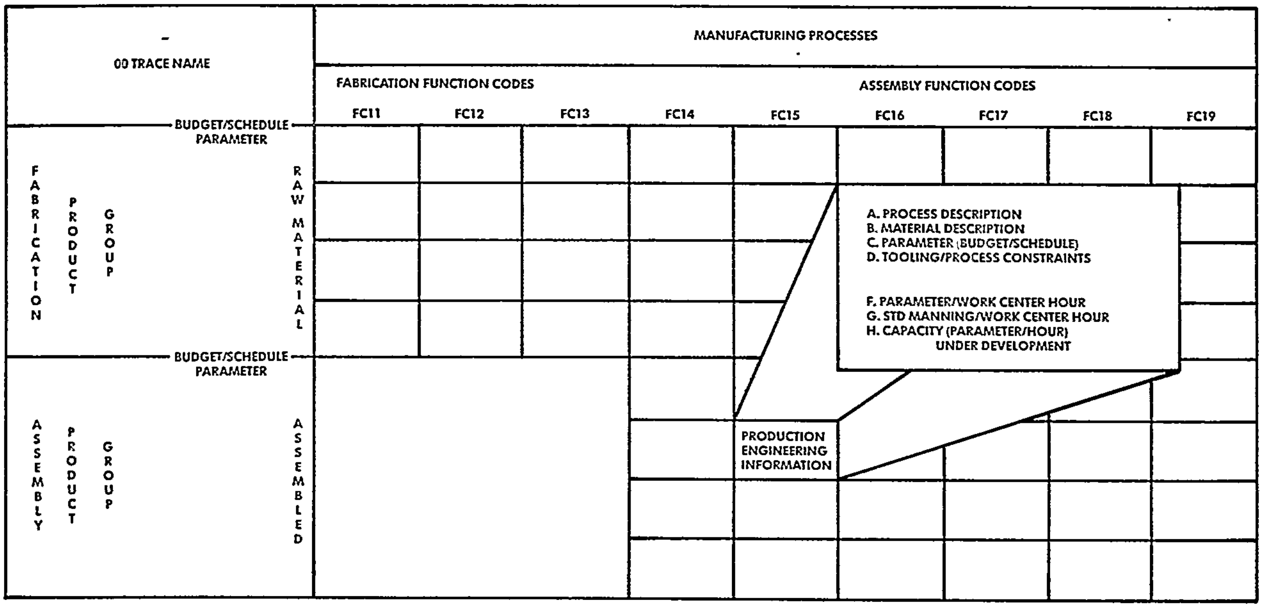


FIG. 3 INTERIM PRODUCT/CONSTRUCTION PROCESS MATRIX

The products are subdivided into two categories: raw materials (including purchased components) and assemblies. The manufacturing processes were found to be similar for all trades and are also divided into two categories: fabrication and assembly.

Raw material is staged for the fabrication processes of cutting and bending. Fabricated components and purchased components are inspected and kitted for the assembly processes of assembly, joining, finishing, quality assurance, and kitting for a later stage in the construction process. These manufacturing processes are further defined by the following function codes:

- FC 11 QUEUE - Raw material sorting, moving, kitting, etc.
- FC 12 CUTTING - Burning, shearing, sawing, etc.
- FC 13 BENDING - Bending, forming, flanging, etc.
- FC 14 Q & QC - Fabricated material queue, kitting and quality control
- FC 15 ASSEMBLY - Assembly of parts
- FC 16 JOINING - Welding, brazing, bolting, etc.
- FC 17 FINISHING- Grinding, pickling, coating, etc.
- FC 18 QA - Quality Assurance

FC 19 KITTING - Kitting for installation pallet by Product Work Breakdown Structure

The Product/Process Matrix is the tool for systematically identifying the Production Engineering Information required to support effective implementation of a CAPP System. The following Production Engineering Information will complete the matrix for each fabrication shop or assembly area:

- <u>Detailed Process Descriptions</u> - Complete description of each of the different manufacturing process methods available for a given product, including the decision logic followed in determining which method is used.
- <u>Detailed Material Descriptions</u> - Complete descriptions of the raw materials that are typically processed by the shop such as material type and maximum and minimum sizes.
- <u>Tooling and Process Constraints</u> - The capacity constraints for each method described in the Detailed Process Descriptions as well as the handling constraints (size and weight).
- <u>Work Content Parameters</u> - Work content parameters (hereafter referred to as parameters), a work measurement tool, to determine the amount of labor required to complete a task for each interim product. (Examples include the number of pieces to be fitted, the linear feet of weld joint to be fitted, the weld pass length (number of passes X linear feet of weld joint) to be welded, number of pipe pieces to be installed, etc.)
- <u>Efficiency Rates</u> - Efficiency rates calculated by dividing the work content parameter value by the hours required to complete the task.
- <u>Standard Manning Levels</u> - The number of persons that can efficiently be assigned to a interim product, for each specific work site.
- <u>Capacity</u> - Stated as Parameter/Hour, capacity for a work station is calculated by multiplying the Efficiency Rate by the Standard Manning level for each station.

<u>Interim Product/Construction Process Matrices</u>

Product/Construction Process matrices have been developed for each of the BIW fabrication shops. Included in the matrices are examples of the Production Engineering Information covering the detailed process descriptions and the materials used by each shop. Figures 4 and 5 are examples of such matrices. The balance of the BIW manufacturing data is considered proprietary, however, typical examples are provided in Figure 6 to enable the reader to gain a clear understanding of the concepts involved.

Figure 6

Weld Length Efficiency Rates for Structural Shops and Ways

Area	Efficiency Rate (Ft/Hr)
Panel Shop	14.07
Curved Panel Shop	9.73
Assembly Shop	1.51
Ways	0.60

<u>INTERIM PRODUCT FLOW</u>

The material in a fabrication shop spends more of its time in queue or moving from one work site to another than it does in "value added" activities. The flow of material, as well as the queue time, must be known for each interim product family in order to assign schedule durations for each of the products. In a shop where Group Technology (GT) has not been applied to identify interim product similarities, such products are generally handled as unique items and, hence, any data that may have been accumulated to record work site efficiencies or cycle time will vary widely. Once the flow path for "value added" work sites for a particular interim product family is established, the processes can be analyzed, production engineering data gathered and changes with known impacts can be accomplished to improve the productivity.

In developing data for a shipyard CAPP system it is apparent in all shops that the flow path options for material between actual work sites in a shop are nearly infinite. However, when viewed from a GT perspective, the problem becomes manageable. Once again, it is the application of an old technology to form the manufacturing data base for the CAPP triangle.

PRODUCT	QUEUE	CUTTING	BENDING	Q&QC	ASSEMBLY	JOINING	WELDING	QA	KITTING
PLATE	SQ FT								
PARALLEL EDGE PLATE PARTS NON-PARALLEL PLATE PARTS INTERNAL PLATE PARTS	SEQUENCE SORT BLAST/PRIME CONVEY INSIDE STACK	MACH BURN MANUAL BURN SHEAR SAW PUNCH SHEAR	BEND ROLL LINE HEAT FLANGE PUNCH	TO BATH TO WEB LINE TO BULKHEADS TO FOUNDATION TO MISC SMALL PARTS TO COMPLEX 3-D				INSPECT STATUS REPORT	SORT TRESSEL STORE SHIP
SHAPES	LIN FT	—	—	—	—	—	—	—	—
PREFABBED SHAPE INTERNAL PARTS	SEQUENCE SORT BLAST/PRIME CONVEY INSIDE STACK	LAYOUT MANUAL BURN SHEAR	FRAME BEND LINE HEAT TWIST PUNCH DRILL STRAIGHTEN	TO BATH TO WEB LINE TO BULKHEADS TO FOUNDATION TO MISC SMALL PARTS TO COMPLEX 3-D				INSPECT STATUS REPORT	SORT TRESSEL STORE SHIP
WEBS & GIRDERS	—	—	—	—	WELD LENGTH	—	—	—	—
WEBS & GIRDERS FROM SHAPES WEBS & GIRDERS FROM PLATES WEBS & GIRDERS FROM BOTH				FROM SHAPES FROM PLATES FROM MISC SMALL PARTS	LAYOUT POSITION TACK	JOIN TO BULKHEADS TO FOUNDATION TO COMPLEX 3-D	WELD INSPECT PICK-UP	INSPECT STATUS REPORT	SORT RACK STORE SHIP
BULKHEADS, DECKS, & PLATFORMS	—	—	—	—	WELD LENGTH	—	—	—	—
SINGLE PLATE BULKHEAD SINGLE PLATE BULKHEAD W/WEBS MULTIPLE PLATE BULKHEAD MULTIPLE PLATE BULKHEAD W/WEBS				FROM PLATES FROM SHAPES FROM MISC SMALL PARTS FROM WEBS & GIRDERS	JOIN PLATES LAYOUT FRAMING TACK	WEBS & GIRDERS TACK TO COMPLEX 3-D	WELD INSPECT PICK-UP	INSPECT STATUS REPORT	SORT TRESSEL STORE SHIP
FOUNDATIONS	—	—	—	—	—	—	—	—	—
SIMPLE FOUNDATION FROM SHAPE SIMPLE FOUNDATION FROM PLATE SIMPLE FOUNDATION FROM BOTH COMPLEX FOUNDATION FROM SHAPE COMPLEX FOUNDATION FROM PLATE COMPLEX FOUNDATION FROM BOTH		LAYOUT MANUAL BURN PORT PLASMA	ROLL FLANGE SHEAR BEND DRILL	FROM PLATES FROM SHAPES FROM MISC SMALL PARTS FROM WEBS & GIRDERS	WELD LENGTH POSITION TACK	TO BULKHEADS TO COMPLEX 3-D	POSITION WELD INSPECT PICK-UP	INSPECT STATUS REPORT	STORE PICK TRAILER SHIP
MISC SMALL PARTS	—	—	—	—	WELD LENGTH	—	—	—	—
MISC SMALL PARTS FROM PLATE MISC SMALL PARTS FROM SHAPE MISC SMALL PARTS FROM BOTH				FROM PLATES FROM SHAPES	LAYOUT FIT TACK	TO WEB LINE TO BULKHEADS TO FOUNDATION TO COMPLEX 3-D	POSITION WELD INSPECT PICK-UP	INSPECT STATUS REPORT	BOX OR PALLET STORE PICK TRUCK SHIP
DOORS, HATCHES, SCUTTLES	—	—	—	—	QUANTITY	—	—	—	—
(ANY DOOR, HATCH, OR SCUTTL THAT IS)100 LBS SHOULD BE BUILT ON A TABLE IN FOUNDATION AREA)				FROM PLATES FROM SHAPES FROM MISC SMALL PARTS		LAYOUT POSITION TACK TURN BACKFIT	POSITION WELD POSITION WELD INSPECT PICK-UP	INSPECT STATUS REPORT	STORE PICK TRAILER SHIP
COMPLEX 3-D ASSEMBLIES	—	—	—	—	WELD LENGTH	—	—	—	—
COMPLEX 3-D FROM PLATES COMPLEX 3-D FROM SHAPES COMPLEX 3-D FROM BOTH COMPLEX 3-D FROM BOTH (INCLUDING WEBS, GIRDERS, BULKHEADS, MISC SMALL PARTS, FOUNDATIONS, OR ANY COMBINATION OF THESE				FROM PLATES FROM SHAPES FROM MISC SMALL PARTS FROM WEBS & GIRDERS FROM BULKHEADS		LAYOUT POSITION TACK TURN BACKFIT	POSITION WELD POSITION WELD INSPECT PICK-UP	INSPECT STATUS REPORT	STORE PICK TRAILER SHIP

FIG. 4 STRUCTURAL FABRICATION INTERIM PRODUCT/CONSTRUCTION MATRIX

PRODUCT	QUEUE	CUTTING	BENDING	Q&QC	ASSEMBLY	JOINING	FINISHING	QA	KITTING
PIPE	LIN FT								
FERROUS NON-FERROUS ALUMINUM	DRAW	SAW	LAYOUT BEND	TO KITTING TO PIPE ASSEMBLY TO OUTFIT PACKAGE				INSPECT STATUS REPORT	KIT TRANSPORT
HOSE	LIN FIT	—	—		—	—	—	—	—
	DRAW	SAW		TO KITTING TO HOSE ASSEMBLY TO OUTFIT PACKAGE				INSPECT STATUS REPORT	KIT TRANSPORT
HANGER MATERIAL	LIN OR SQ FT	—	—	—	—	—	—	—	—
	DRAW	CUT	BEND	TO KITTING TO HANGER ASSEMBLY TO OUTFIT PACKAGE				INSPECT STATUS REPORT	KIT TRANSPORT
WAVE GUIDE	LIN FT	—	—	—	—	—	—	—	—
	DRAW	SAW	BEND	TO KITTING TO WAVE GUIDE ASSEMBLY				INSPECT STATUS REPORT	KIT TRANSPORT
PURCHASED FOR ASSEMI	QUANTITY	—	—	—	—	—	—	—	—
				TO PIPE ASSEMBLY TO HOSE ASSEMBLY TO WAVE GUIDE ASSEMBLY TO OUTFIT PACKAGE				INSPECT STATUS REPORT	KIT TRANSPORT
ASSEMBLED PIPE	—	—	—	LIN FT	—	—	—	—	—
PIPE WITH 0-1 FITTINGS PIPE WITH 2-5 FITTINGS PIPE WITH 5 OR MORE FITTINGS				FROM PIPE FROM PURCHASED FROM HARDINGS FROM MACHINE SHOP	LAYOUT FIT PREP BRAZE OR WELD		TEST INSPECT CLEAN COATINGS	INSPECT STATUS REPORT	KIT TRANSPORT
HOSE ASSEMBLY	—	—	—	LIN FT	—	—	—	—	—
				FROM HOSE MATERIAL FROM PURCHASED	LAYOUT ATTACH FITTINGS		CLEAN TEST	INSPECT STATUS REPORT	KIT TRANSPORT
WAVE GUIDE ASSEMBLY	—	—	—	LIN FT	—	—	—	—	—
				FROM WAVE GUIDE MATERIAL FROM PURCHASED	LAYOUT ATTACH FITTINGS	ASSEMBLE	TEST CLEAN PROTECT	INSPECT STATUS REPORT	KIT TRANSPORT
HANGER ASSEMBLY	—	—	—	QUANTITY	—	—	—	—	—
					LAYOUT ASSEMBLE	WELD	CLEAN PRIME	INSPECT STATUS REPORT	KIT TRANSPORT
OUTFIT PACKAGE	—	—	—	LIN FT	—	—	—	—	—
				FROM PIPE FROM PURCHASED FORM HARDINGS FROM MACHINE SHOP FROM ASSEMBLED PIPE FROM HANGER ASSEMBLY FROM HOSE ASSEMBLY	LAYOUT ASSEMBLE WELD OR BRAZE	BOLT ASSEMBLIES	TEST CLEAN PAINT	INSPECT STATUS REPORT	KIT TRANSPORT

FIG. 5 PIPE AB INTERIM MATRIX

Interim Product Flow Logic

As in any Industrial Engineering analysis of a material flow problem, the present flow must be determined. Using the fabrication plant layouts, the interim product flow paths are determined. Figure 7 is an example of the material flow in a structural fabrication shop. A natural result of this effort is the identification of "bottlenecks" and "multiple travel paths". The rearrangement of the facility and/or improved organization of material can frequently result in improved interim product flow. As a result of identifying the present material flow, a future material flow layout is prepared. This is simply a plant layout with an improved hopefully "optimum" material flow indicated on the layout. Figure 8 is an example of a proposed material flow aluminum bulkheads. The process of drawing such layouts results in the identification of "value added" work sites, travel distances, travel times, handling frequencies and queue times. All of this information is essential for the development of an effective CAPP system.

In parallel with the material flow layout development. interim product flow diagrams are produced as an expansion of the interim product/ construction process matrices. Separate flow diagrams are developed for each interim product family with all potential "value added" process paths displayed. The flow diagrams are used to analyze the "value added" activities that occur for each product. The term "value added" refers to those processes which add to the worth of the interim product such as cutting a bar or plate to size, shaping a bar or plate, and/or joining two or more pieces together to form an assembly. This effort also identifies "bottle-necks" in the process flow. This is determined by applying the most probable manning and efficiency rates for a specific work site against the work to be completed at that site. The "bottleneck" is the work site with the longest cycle time.

Sample Interim Product Flow Diagrams

Completed material flow diagrams provide the information necessary to identify the "value added" points in the material flow. These points or work sites are identified on the flow diagram. An example diagram is presented for the structural fabrication shop in Figure 9.

It is readily apparent that learning curve efficiencies can be achieved over a short period of time by maintaining a consistent flow within a shop. It also is apparent that the supervisors of shop floor flow control frequently make changes in a sincere effort to improve productivity without being able to analyze the impact of such changes.

The implementation of a CAPP system provides the tools to analyze such changes prior to their implementation.

BUDGET AND SCHEDULE PARAMETERS

One of the key elements of manufacturing data in CAPP is the work measurement tool - "parameter". A parameter is a measurable attribute that will reflect the work content in an interim product. Work content is a measure of the amount of work to be accomplished at a work station. An interim product is any of the products defined as a part of a family of products in the interim product/ construction process matrices defined in the preceding paragraphs. The foreward of the Department of Defense MIL-STD-1567A "Work Measurement" states:

> "Experience has shown that excess manpower and lost time can be identified, reduced and continued method improvements can be made regularly, where work measurements programs have been implemented and conscientiously pursued.
>
> "Active support of the program by all affected levels of management, based on an appreciation of work measurement and its objectives. is vitally important. Work Measurement and the reporting of labor performance is not considered an end in itself but a means to more effective management. Under- standing the implication inherent in the objectives of the work measurement program will promote realization of its full value. It is important that objectives be presented and clearly demonstrated to all personnel who will be closely associated with the program.
>
> "The following are benefits which can accrue as a result of the employment of a work measurement program:
>
> (a) Achieving greater output from a given amount of resources

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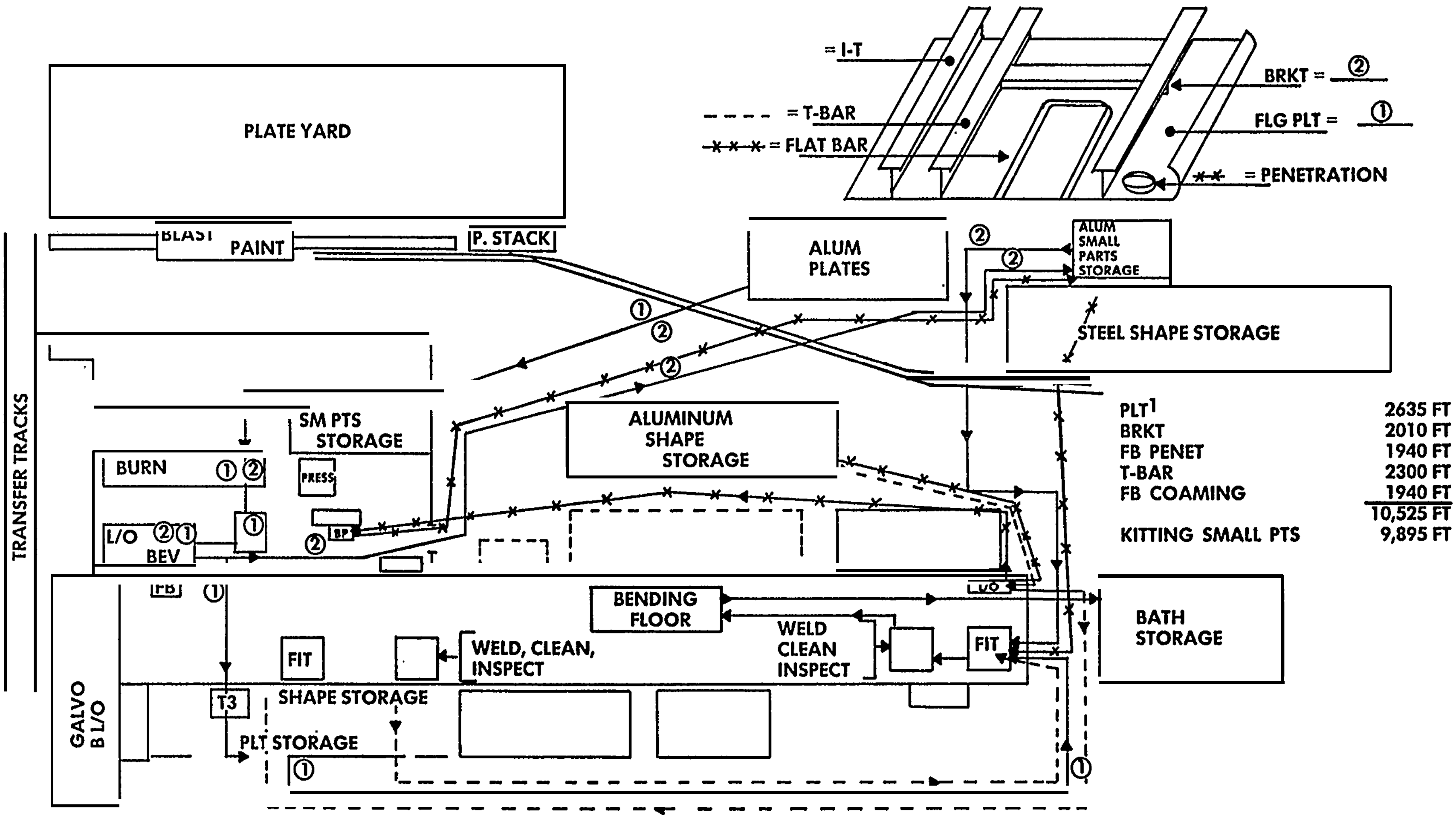

FIG. 7 ALUMINUM BULKHEAD MATERIAL FLOW RE

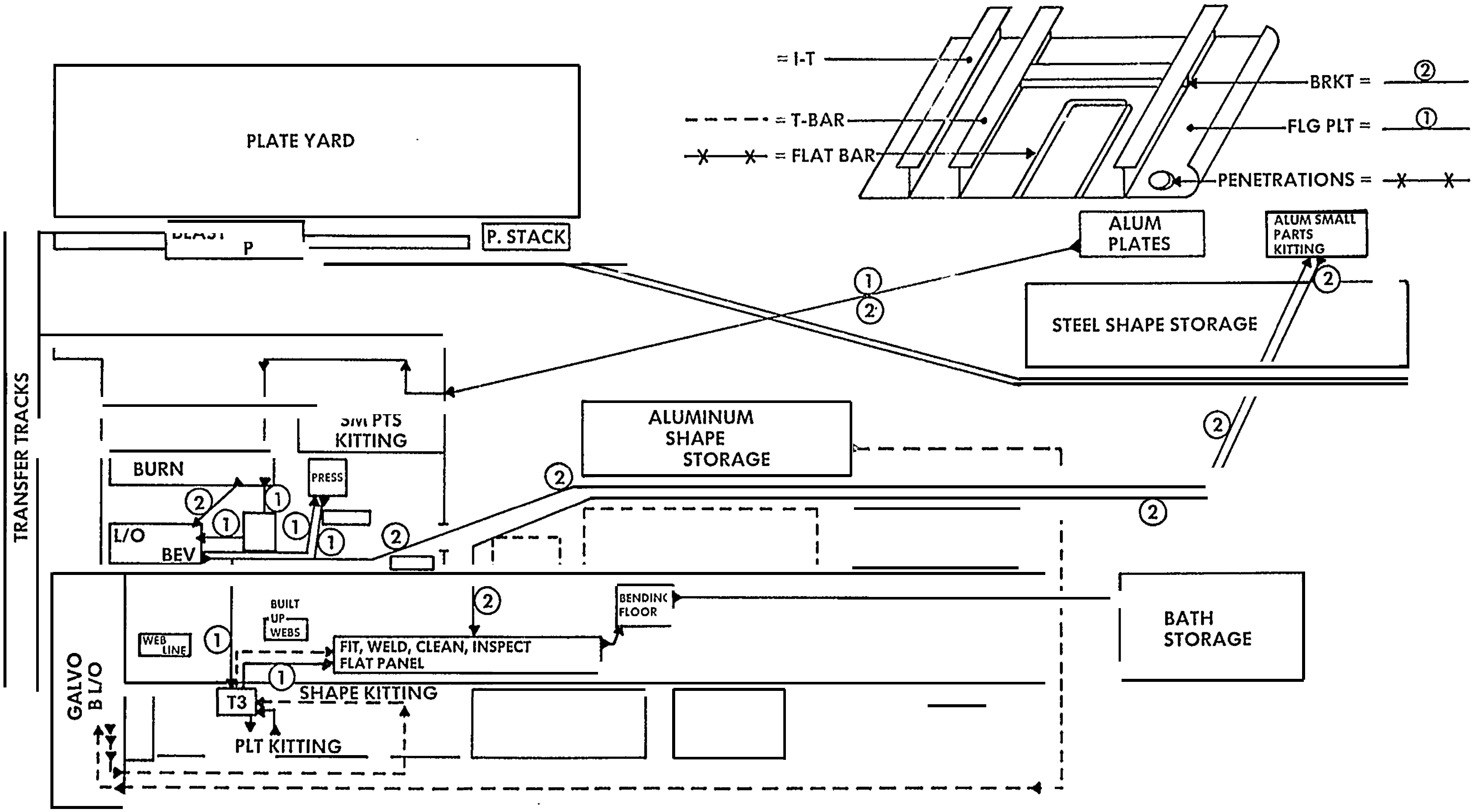

FIG. 8 ALUMINUM BULKHEAD MATERIAL FLOW (FUTURE)

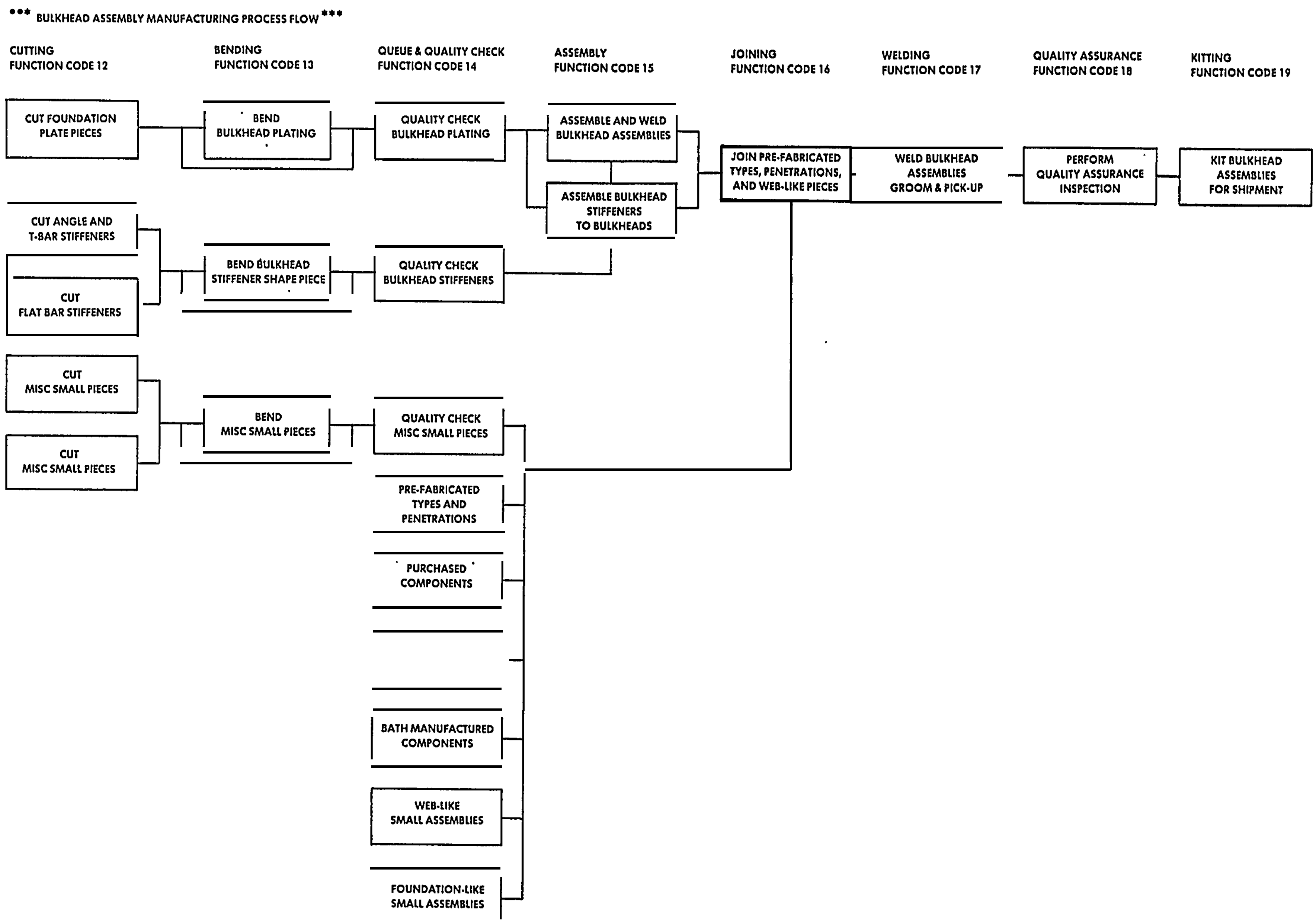

FIG. 9 BULKHEAD ASSEMBLY PROCESS FLOW

(b) Obtaining lower unit cost at all levels of production because production is more efficient

(c) Reducing the amount of wasted time in performing operations

(d) Reducing extra operations and extra equipment needed to perform these operations

(e) Encouraging continued attention to methods and process analysis because of the necessity for achieving improved performance

(f) Improving the budgeting process and providing a basis for price estimating, including the development of Government Cost Estimates and should-cost analyses

(g) Acting as a basis for the planning of long-term manpower equipment, and capital requirements

(h) Improving production control activities and delivery time estimation

(i) Focusing continual attention on cost reduction and cost control

(j) Helping in the solution of layout and materials handling problems by providing accurate figures for planning and usage of such equipment

(k) Providing an objective and measured base from which management and labor can project piece-work requirements, earnings and performance incentives.

Without work content measurement tools, the accuracy of a Computer Aided Process Planning (CAPP) system will be reduced considerably and the plan would soon be abandoned due to shop floor congestion or under use as a result of inaccurate cycle times.

Many elements can be used for work content measurement. Example parameters are provided as follow:

EXAMPLE PARAMETERS

Structural Fabrication

	Parameter
Marking/Burning	
Numerical control marking and burning	PL
Flame Planner	PL
Telerex	PL
CM-56 Parts Cutter	PL
Manual marking	PL
Manual burning	PL
Profile cutting	P
Bending	
Profile bending	P
Plate bending	PL
Small piece bending	P
Subassembly	
Fitting	FT
Welding	FT
Finishing	FT
Others	
Material handling	Tons
Shot blasting	PL
	P
Painting	PL
Flat Assembly	
Plate joining	FT
Fitting	FT
Welding	FT
Finishing	FT
Curved Assembly	
Preparation	Tons
Plate joining	FT
Fitting	FT
Welding	FT
Finishing	FT
Pipe Fabrication	
Pipe	Lin Ft
Hose	Lin Ft
Hanger material	Lin Ft
Wave Guide	Lin Ft
Material handling	Qty
Fittings. flanges, etc.	Qty
Assembled pipe	Qty
Ferrous	Qty
Non-ferrous	Qty
Hose assembly	Lin Ft
Wave Guide assembly	Lin Ft
Hanger assembly	Qty

Sheet Metal Fabrication

	Parameter
sheet Goods	
Grating	Sq Ft
Honeycomb panels	Sq Ft
Plate 1/2”	Sq Ft
Sheet metal	Sq Ft
Shapes	
Angle	Lin Ft
Channel (Deck Shoes)	Lin Ft
Extrusions	Lin Ft
Flat bar	Lin Ft
Pipe or tubing	Lin Ft
Purchased for Assemblv	
Comm. equipment	Qty
Cooling coils	Qty
Dampers	Qty
Filter housings	Qty
Gauges	Qty
Heaters & reheaters	Qty
Terminal ends	Qty
Thermostats	Qty
Vent valves	Qty
Rectangular vent	Lin Ft
Round vent	Lin Ft
Foundations	
Simple foundations	Qty
Complex foundations	Qty
2D & Simple 3D	
Access covers	Qty
Cable protectors	Qty
Control panels	Qty
Deck coaming	Qty
Draft marks	Qty
Fire extinguishing fdns	Qty
File stations	Qty
Flange shields	Qty
Floor plates	Qty
Fume tight collars	Qty
Gooseneck	Qty
Grab rods	Qty
Guage boards	Qty
Hangers	Qty
Joiner curtain frames	Qty
Joiner curtain plates	Lin Ft
Ladders	Qty
Light traps	Qty
orifice plates	Qty
Pans	Qty
Penetrations	Qty
Pipe battens	Qty
Protective covers	Qty
Sheathing	Sq Ft
Shelves	Qty
Stowages	Qty
Vent air lifts	Qty
Vent dampers	Qty
Vent flanges	Qty
Vent screens	Qty
Vent terminals	Qty

Exhaust Ducting Intakes/Uptakes

Corten	Lin Ft
Expansion joints	Qty
Sheathing	Sq Ft

Complex 3-D Assembly

Benches	Qty
Berths	Qty
Bins	Qty
Boxes	Qty
Bulk stowages	Qty
Cabinets	Qty
Commissary equipment	Qty
Counters	Qty
Coupling covers	Qty
Drawers	Qty
Dressers	Qty
Hinged shelves	Qty
Hoods	Qty
Installation fixtures	Qty
Ladders	Qty
Lockers	Qtv
Louvers	Qty
Priming chambers	Qty
Power & lighting panels	Qty
Racks	Qty
Service stands	Qty
Sinks	Qty
Stowages	Qtv
Tanks	Qty

Reefer Construction

Reefer boxes	Cu Ft

Electrical Fabrication

	Parameter
Electrical Equip Foundations	Qty
Cable trays	Qty
Light legs	Qty
Terminal boxes	Qty
Distribution boxes	Qty
Complex Manufactured Equipment	Qty
Power Panels	Qty
Switchboards	Qty
Controllers	Qty
Miscellaneous	
Pre-Plug Special Cable	Qty
Purchased or GF Equipment	Qty

Miscellaneous Fabrications

	Parameter
Grating	Sq Ft
Steel	Sq Ft
Aluminum	Sq Ft
Diamond plate	Sq Ft
Operating gear material	Lin Ft

Miscellaneous Fabrications Cont'd)

	Parameter
Shapes	Lin Ft
I-Beam	Lin Ft
Angle bar	Lin Ft
Flat bar	Lin Ft
Round bar	Lin Ft
Wire rope	Lin Ft
Purchased for assembly	Qty
Grating assembly	Sq Ft
Operating gear assembly	Lin Ft
CO_2 pull assembly	Lin Ft
Outfit package	Spc Est
Label plates	Qty

Abbreviations

H = Hour	P = Piece
PL = Plate	FT = Foot
Ton = Long Ton (2,240 lbs.)	Lin = Linear
Sq = Square	Qty = Quantity

Budget and Schedule Parameters Logic

A parameter is simply a measurement of the work content in a task that needs to be completed. It may be the square footage of surface to be blasted or painted, the number of bolts to be installed, or the footage of weld to be deposited. Once the task can be determined by dividing the work content by the time required to complete the task.

$$\text{Efficiency rate} = \frac{\text{Work Content}}{\text{Time}}$$

The efficiency rate is highly dependent on the method used and stage of construction involved, however, for individual work stations it has proven to be very constant. Process changes at a work station or the addition of jigs and fixtures will change the efficiency rate. However, the change should be known in advance because a cost benefit analysis should be completed prior to incorporation of the change.

There are two types of efficiency rates as defined by MIL-STD-1567A. They are defined as follows:

> "Type I Engineered Labor Standards. These are standards established using a recognized technique such as time study, standard data, a recognized predetermined time system or a combination thereof to derive at least 90% of the normal time associated with the labor effort covered by the standard and meeting requirements of paragraph 5.1. Work sampling may be used to supplement or as a check on other more definitive techniques.
>
> **"Type I Engineered Labor Standards. All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level. For short operations, the accuracy requirement may be better met by accumulating small operations into super operations whose times are approximately one-half hour. Type I standards must include:**
>
> a. Documentation of an operations analysis
>
> b. A record of "standard practice or method followed when the standard was developed
>
> c. A record of rating or leveling
>
> d. A record of the standard time computation including allowances
>
> e. A record of observed or predetermined time system time values used in determining the final standard time.
>
> " Type II Labor Standard. All labor standards not meeting the criteria established in paragraph 5.1."

Type I standards are similar to the Maynard Operating system Technique (MOST) data compiled between 1979 and 1985 for the National Shipbuilding Research Program. Figure 10 is an example of such data. Some of these standards can be utilized in implementing a CAPP system. Another example of Type I data is the numerically controlled cutting data available from the AUTOKON data base in the BIW mold loft. Figure 11 is an example of such data. It is noted that the parameter for both types of efficiency rates could be the same. The parameters selected for use at an individual shipyard will most likely be unique for that shipyard.

7.0 STANDARD TIME CALCULATIONS

7.1 Fitting Operations (Level Time) Factors for Hyde Assembly Shop

C. Shell Sub-Assemblies on 90° Diaphragm Mocks

Fitting Operation	Hour/Factor	"MOST" No.
Set, Regulate & Secure (flat assemblies):		
Plates on Mock (mild steel plate)	1.574/ea.	12,30,40
(HY-80)	2.249/ea.	12,30.41
Stringers	.232/ea.	23,30
Webs	.214/ea.	13.30
Set, Regulate & Secure (radius shell assemblies):		
Plates on Mock (mild steel plate)	2.814/ea.	11,12,16.30
(HY-80)	3.097/ea.	11,12,17,30
Stringers	.350/ea.	30,42
Webs	.214/ea.	13,30
Make-up fit & Tack (flat assys): *Shell Seams & Butts		
(mild steel plate)	.048/ft.	14,18
(HY-80)	.099/ft.	15,19
Stringers to Shell (to mild steel)	.023/ft.	24
(to HY-80)	.045/ft.	25
Webs to shell (to mild steel)	.063/ft.	26
(to HY-80)	.098/ft.	27
Make-up fit & Tack (flat assys): *Shell Seams & Butts		
(mild steel plate)	.048/ft.	14,18
(HY-80)	.099/ft.	15,19
Stringers to Shell (to mild steel)	.028/ft.	43
(to HY-80)	.052/ft.	44
Webs to Shell (to mild steel)	.063/ft.	26
(to HY-80)	.098/ft.	27

* Make-up of shell seams also includes installation of strong backs.

FIG. 10 TYPE I PRODUCTION STANDARD EXAMPLE

NESTED FORMAT = 4010 / 34

CUTTING INFORMATION

CONTOUR PART	TIME MIN : SEC	LENGTH FT-IN-16	SPEED IN/MIN
CUTTING	= 198=10	455-01-11	27.559
RAPID TRANVERSE	= 11= 6	182-01-11	196.850
MARKING	= 1= 9	2-07-15	27.559
REMAINING	= 0=10	0-04-13	27.559
71 PREHEATING	= 7= 6		
TOTAL	= 217=41	640-04-02	

USED PLATE

AREA	WEIGHT	%/TOTAL
217.323	8149.612	62.092

FIG. 11 AUTOKON PRODUCTION DATA

structural Fabrication Scheduling

In reviewing scheduling and material flow the most significant factor observed was that "in-process" material remains in queue a much longer time when compared to the "value-added" time at the work site. (Value-added time is that period of time when work is performed on the interim product to increase its value.) The shop schedule, from the master schedule point of view, is a "window" of time for each unit. To control material and manage the process, both the material and the interim products are presently managed by unit in most U.S. shipyards. In identifying interim products for the present unit construction philosophy it is evident that the flow is as shown in Figure 12. The interim products remaining in queue result in shop floor congestion that hampers the productivity of the shop. Multiple flow paths and different construction approaches for similar products negate any learning curve benefits that can be realized based on interim product similarities.

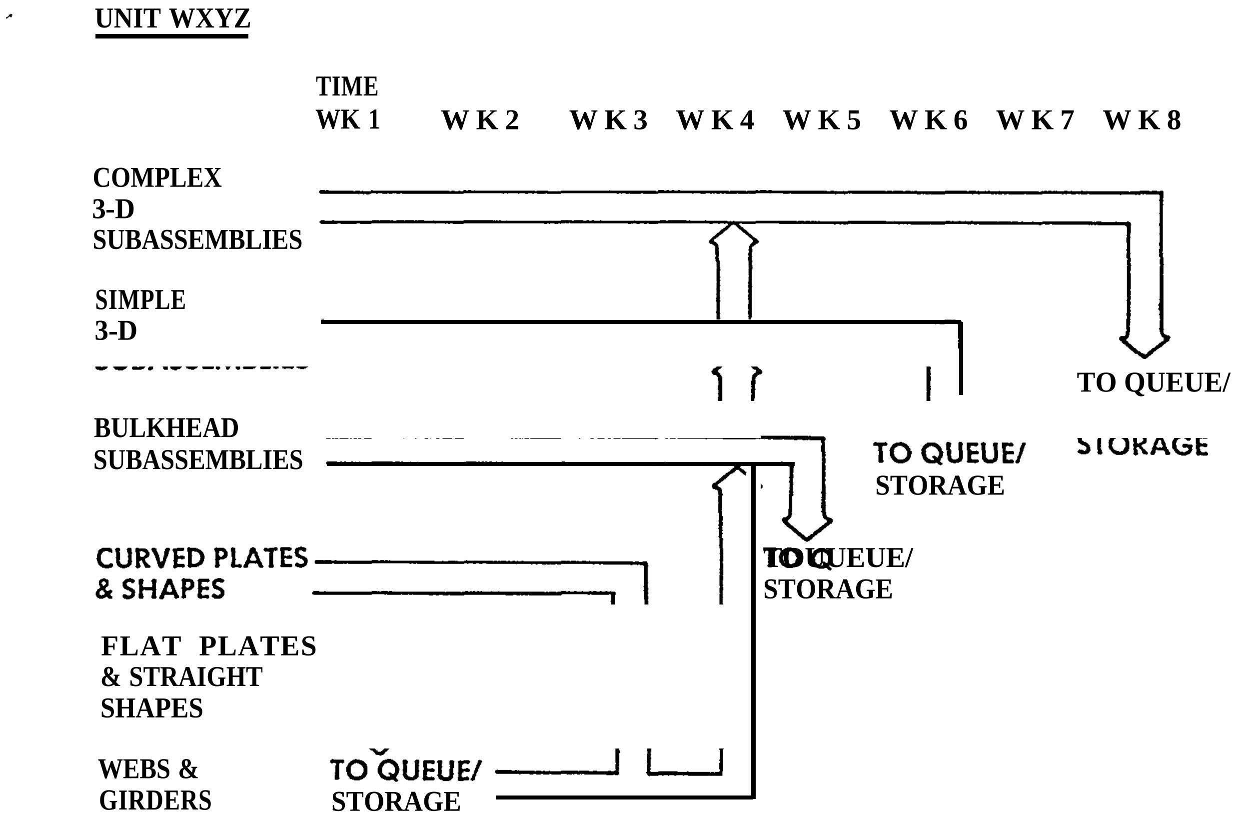

FIG. 12 UNIT FABRICATION SCHEDULE

If a problem with material availability arises. the entire unit is delayed even though its total "value added" time in the cycle is short. When material problems arose during construction, the entire unit construction is halted for several weeks while waiting for a replacement from a raw material supplier.

With the recognition of the interim product/construction process relationship it is possible to further subdivide the unit into similar products and schedule the "value added" time in the shop. Figure 12 is then revised as shown in figure 13.

Integrating interim products across several units demonstrates that a process lane can be level-loaded based on relatively constant efficiency rate returns from each of the work centers.

The manning level at an individual work site is the major factor responsible for meeting schedule needs. With the refinements in the work content measurement approach and efficiency rate returns not only are the schedules more accurate but the projected manning requirements accuracy is increased, thus allowing shop management to more effectively manage the effort.

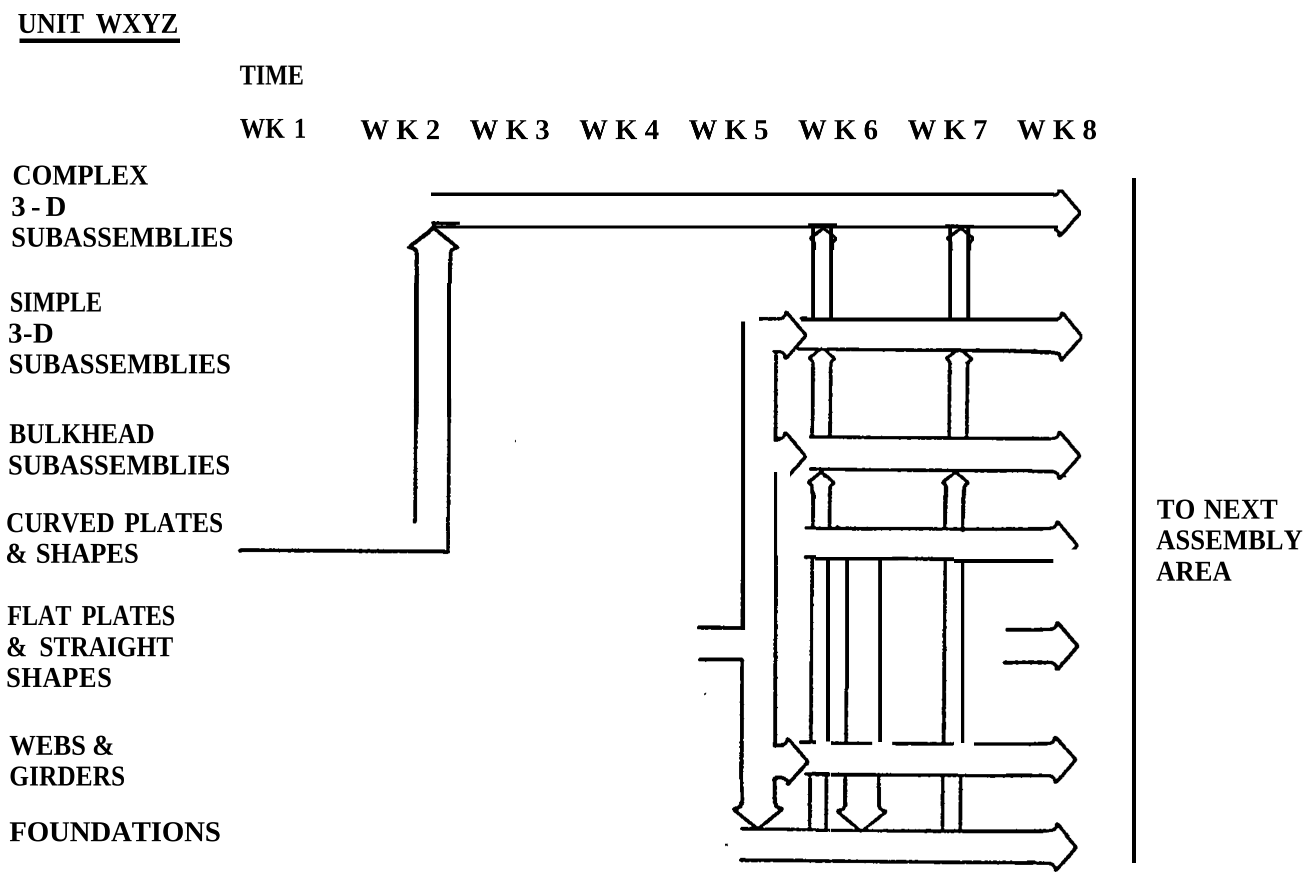

FIG. 13 INTERIM PRODUCT FABRICATION SCHEDULE

To meet the dynamics of shop floor control it is necessary to provide weekly updated schedules that cover a relatively short period. Examples of such schedules are shown in Figures 15-17. These provided a realistic schedule to each station in the shop.

To meet the management needs for shop manning, a three month schedule is provided. Again, each work station is scheduled with a total shop integration to achieve the best possible level-loading of personnel.

CAPP SYSTEMS EVALUATION

The factors required in the manufacturing environment for a Computer Aided Processing Planning (CAPP) system are:

- o A clear identification of product families
- o A clear identification of related processes
- o A consistent vocabulary
- o A simple coding scheme
- o A simple work content measurement tool
- o A measurable definition of shop/process lane capacity
- o An accurate schedule based on shop capacity
- o A clear identification-of required material flow control documentation
- o An identification of data base requirements.

The interim product/process model described in the preceding paragraphs requires that the output from a CAPP system include the following:

- o A process plan for the item to be manufactured based on "product family" characteristics. The process plan should group products with similar manufacturing process requirements in support of process flow lane concepts. There may be several process plans that exist in the individual planner's memory or personal data. These process plans should be accumulated and then combined for optimium effectiveness or

1.25' x 50' FLAT PANEL AREA
2.25' x 50' FLAT PANEL AREA
3.25' x 5O' FLAT PANEL AREA
4.25' x 50' FLAT PANEL AREA
5.10' x 31'TABLE
6, l5'X 30' TABLE
7. B/U WEBB TABLES
8. RUDDER MOCK AREA
9.25' x 50' MI$.C LARGE AREA
10.25' x 50' MISC LARGE AREA
11. 25' x 50' MISC ALUM, MISC LARGE, SPY
12. MISC SMALL STL FIT AREA
13. MISC SMALL STL WELD AREA
14. MISC SMALL STL FIT & WELD AREA
15. MISC SMALL ALUM WELD & CLEAN AREA
16. MISC SMALL ALUM FIT AREA
17. MISC SMALL STL FIT & WELD AREA
18. INDUSTRIL/MISC AREA, TABLES

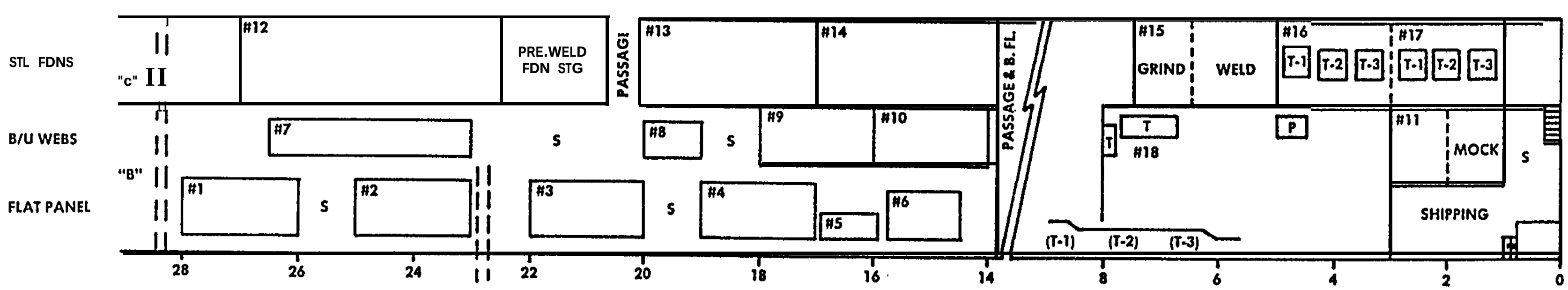

FIG . 14 ASSEMBLY AREAS - STRUCTURAL FABRICATION SHOP

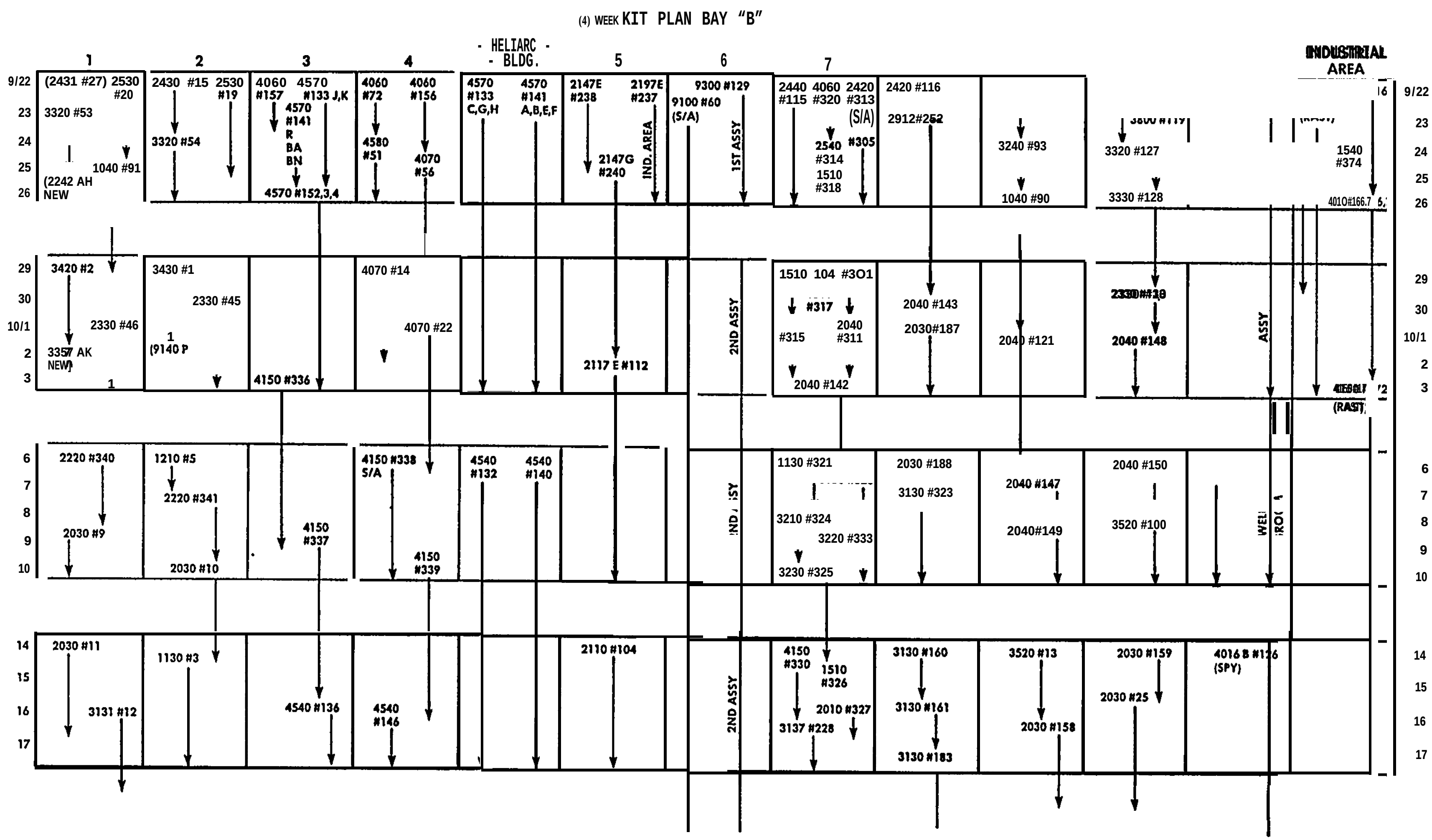

FIG. 15 ASSEMBLY AREA SHORT TERM SCHEDULE

MLJ 9-22-86

HULL / UNIT	KIT #	9-22	9-23	9-24	9-25	9-26		9-29	9-30	10-1	10-2	10-3
1-4050	28 Z	REMAKES										
1-9533	131											
1-4020	253A											
2-2140	239A											
2-2140	241											
2-2241.2	266											
2-2120	261 A											
2-3122,6,7,8	229							A'D KIT				
	230											
2-9506	103											
1-4410	280											
WO HPO-068												
1-3800 SZ	276											
2-2933 OP	231											
1-4010	352							JOBS -IT, U 2 H,J,K,L,M,N,R,T,U,V,AC			AD KIT	
2-2546,7,8	285											
2-9511	248											
1-4580	109											
1-2526 F	REV											
1-2236,7,8	282											
	282 A											
1-2765 B	REV											
420-9523 D	SS 801 B											
WO# 07-2276	2912 P											
2-9516	291											
2-9521 E	363											
1-9251 BF	NEW											
1-1546	374											
1-3358 W	NEW											
2-3310	221 A											
1-9546	196											+
2-2127,8	262											+
	263											+
2-3122,6,7,8	229 A											
1-1536,7,8	272 A											
1-1700 SZ	277											
1-4510	274											+
2-1131,2,6	297 A											
1-4010	352 A											
	351											+
	353											+
	354											+
2-2246,7,8	278											+
2-9511	247											
2-9514	286											+
420-9523 D	SS 718 718 A											
1-1511,2,3,4	299											+
1-1600 SZ	287											
2-1040	201											
2-2110	288											+
												+

FIG. 16 SMALL 3-D ASSEMBLY SCHEDULE

combined and segregated to give the best combinations for the various possible scenarios. This task will enhance the completeness of the plans by expanding them to include step by step sequences. manning requirements, tool requirements. equipment control settings, standard time information. technical data sources and charging instructions.

- Assembly or construction drawings or sketches for each stage of the process. This requires that the design process be integrated with the process plan to maximize the effectiveness of the designer's output.

- Raw material sorting and kitting instructions to direct the right pieces and parts to the right place at the right time. Raw material pick lists and the daily sequencing of raw materials into the shop are examples of raw material requirements output.

- Piece, part, subassembly and assembly kitting instructions for each stage of the process. These instructions should include kitting information for the shop's products in support of the major assembly shops.

- Work content for each stage of the assembly process. The work content parameters used should only be at the level necessary to provide information to level-load the process lanes and provide feedback for shop management for productivity monitoring. The work content information can be utilized with the current efficiency rates to determine accurate budget values and schedule durations. Budgets and schedules will then reflect current methods and shop capabilities and can be generated from a computer program that is a part of the CAPP software.

- A level loaded schedule for each of the stages in the process. This should be prepared on a short term basis only (e.g. two week schedule updated weekly) to support the major milestone schedule.

- Weekly product status and work station performance reports providing clear data to shop management. The data should enable shop management to make short term adjustments to the process plans to respond to problems and changes occurring on the shop floor.

The manually prepared documents currently used to control the flow of material at the structural fabrication shop at BIW are as follows:

- Freight Packing Slip - The packing slip received with the raw material from the shipping company.

- Sorting Instruction Sheet - Provides instructions to the material handlers in the plate yard as to the sequence of plates in each plate stack.

- Daily Sequence Sheet - Provides instructions to the material handlers in the plate yard for the sequencing of plates into the shop.

- Material Issue Requisition - Provides information to the material control system as to what material has been issued against a specific unit or charge.

- Material Transfer Document - Provides information to the material control system to identify material that had been allocated to one unit or charge but had been used on another unit or charge.

- Interdepartment Work Order - A request by one department to provide fabricated material for another department that does not have the capability to fabricate the required material within its own shop.

- Interdepartment Shipping Order - Document used to ship the material on an Interdepartment Work Order.

- Fabrication Shop Internal Shipping Order - Document used to ship loose pieces from the layout areas to the next work station.

- Material Storage Location Form - Document used by layout to ship loose pieces to a storage area.

- o Retraction Document - Document used to control material from a storage area to a work station.
- o Assembly Ordering Form - Document used to request all the pieces and subassemblies to complete an assembly.
- o Left Off List - List of items that were not installed into an assembly because of some production constraint.
- o Delivery Sheet - Document used to control movement of raw material between storage areas.
- o Plate/Shape Loading Sequence Sheets - Document used to load a plate rack and shape rack for shipment of completed material to an assembly site.
- o Short Range Order Form - Document used to control shipment of material to an assembly site.
- o Long Range Order Form - Document used by the assembly shops to notify the fabrication shop of the future material requirements.
- o Bill of Material - A list of all the material required for the assembly of a complete unit.

The required data bases identified for a CAPP system to automatically supply the above lists in the structural fabrication shop include:

- o Material Receiving Data Base
- o Shapes Location Data Base
- o Consolidated Shapes List Data Base
- o Plate Stack Data Base
- o Shop Schedule Data Base
- o Daily Sequence Data Base
- o Loft Summary (Piece and Part) Data Base.
- o Parameter Data Base
- o Efficiency Rate Data Base
- o Nest Data Base.

The proposed Consolidated Shapes List, Data Base and Shop Schedule Data Base allow for computer selection of the "shape process lane" items from the Loft Summary Data Base which can be sorted by shape fabrication and/or layout area. Hard copy printouts of the data for the weekly or daily requirements can be provided directly to the structural fabrication shop. Coupling this information with the structural shape location data base provides a pick list for the raw material handlers. This allows the raw material to be provided to the "shape process lane" area on a "just in time" basis. This information can also be integrated across contracts to allow similar materials to be processed concurrently.

The Plate Stack Data Base, based on a preplanned plate storage area, coupled with the Loft Summary Data Base and the Shop Schedule Data Base can provide a pick list (Daily Sequence Data Base) for the raw plate material handlers. Again. this information can be integrated across all contracts to allow similar grade and thickness material to be processed in batches. The nesting of parts, based on schedule requirements, just prior to shop fabrication can increase the usage of standard sized plates and reduce scrap costs. The Nest Data Base would need to be closely coupled with the material charging system to support cost charging against the proper contracts.

The Material Receiving Data Base provides a real time information source to determine the availability of material for the weekly update of the level loaded work station schedules.

The development and maintenance of these data bases provides consistent data control which facilitates the utilization of bar codes for gathering and entering data. Bar codes for recording charging data, material and interim product identification, kit inventorying, raw material control and material control input information can all be provided on the process plan and kitting documentation to allow for bar code data recording. This can increase data input efficiency by a factor of ten and decrease input error to nearly zero.

Group Technology (GT), as described in the National Shipbuilding Research Program report "Product Work Classification and Coding". is an essential element for product family identifications and for the development of a coding system that rationalizes and simplifies the data base information. Organizing the

information by common attributes that are required by the users limits the size of the data bases. This organization occurs at various stages of design and construction. In addition, structuring the information in a hierarchical fashion limits the amount of data that must be scanned by the computer to integrate the information for each stage of construction.

INPACT ANALYSES OF COMPUTER AIDED PROCESS PLANNING

As shown in Figure 2, Computer Aided Process Planning (CAPP) has an impact on all phases of the shipbuilding process. Some work areas, such as detailed planning. will experience an increased workload due to the additional information that must be developed to operate a CAPP system. However, the total benefits a shipyard can derive from implementing CAPP far outweighs the workload increase in most areas.

Impact on Preproduction Activities

The greatest impact CAPP has on preproduction activities is that the discipline required to support information retrieval during the planning process results in a more structured approach to the development of that information. General standards relating to classification and coding of parts, subassemblies, assemblies and units are developed to provide a common language for all disciplines. This results in overall improved communications and reduced costs. Specific benefits for each area follow:

1. Estimating. Estimating departments primarily derive a benefit because using parameter values allows the estimate to be based on measurable work content. Current Efficiency Rate Returns from the various shops involved reflect current work practices thus providing up-to-date information for the estimating process. The work content data that is developed during the estimating process can be used to measure the design development against the estimated bid, and for the development of baseline budgets after contract award.

   In fact, data throughout the estimating, design and planning process becomes related. Thus, each step in the estimating, program planning. design, and detail planning process is a refinement of the data developed during the previous stage. The tiered development of data supports the application of design budgets during the design phase and enhances the capability of a shipyard to develop an auditable trail of the effect of both engineering changes in design and methods and process changes in production.

2. Program Planning. Computer Aided Program Planning can be applied in much the same manner as Computer Aided Process Planning. Each can use the same work content and efficiency rate data to develop program planning information such as facility loading, standard program plan language, unit sequencing, and preoutfit levels. Manual or variant Computer Aided Program Planning would most economically serve the needs of a shipyard program planning office due to the text type nature of program plans.

3. Program Scheduling. Program scheduling has potentially the most to gain from the use of a CAPP system. The accuracy of the top level schedules can be significantly enhanced by using the work content developed by estimating and the efficiency rate returns and projected manning for the various yard areas.

4. Budgeting. The development of budgets for the tasks to be completed in the various shipyard areas can become a computer exercise when the work content is broken down into the various stages of construction and the applicable efficiency rates are applied. of course, as the design matures and detailed drawings become available the work content values must be refined to reflect work content on the detailed drawings. Changes in work content are then auditable as far back as the estimating process.

5. Material Lift. Material lift will see little impact from a CAPP system unless "Just-in-time" material nesting on standard plates and shapes is

implemented to suit process lane requirements and capabilities. The primary benefit of such implementation is the elimination of uniquely sized plates and multiple length shapes for each unit. BIW has progressed a considerable distance in this area although "Just-in-time" nesting is not in place. on the CG 51 contract over 3500 plate sizes were required to build the structural hull. For one thickness and grade there were over 250 individual sizes. Through cross-nesting between units within given "schedule windows" this number was reduced to about 2500 on CG 58. On DDG 51 there are 36 plate sizes. Although higher scrap rates will occur until "just in time" nesting is implemented the savings in bulk-buys, lower inventory requirements and elimination of delays due to bad plates is sure to pay for the higher scrap costs by tenfold.

6. Production Drawings. Drawings for the fabrication floor could be grouped by interim product type or process. This could lead to an increase in the number of shop drawings that would be needed if unit relationships are maintained or to a decrease in drawings if the unit relationship was only maintained through an interim product identification code and interim products for each family, are grouped on a single drawing. The workload of the designer could increase if the responsibility for work content measurement was placed on the designer. This could have the additional benefit of making the designer aware of the production work content that may be added to the drawing because of the approach taken in the development of the design. The benefit of being able to retrieve similar past designs reduces the design time required because frequently an existing design or one with minor changes will satisfy requirements. This results in fewer designs and a higher level of productivity in the production shop as a result of learning curve benefits.

7. shop Planning. The greatest benefit will be realized in shop planning. The planning process will be automated through the use of variant or generative process planning systems and the accuracy and consistency of the plan produced will improve. In addition, the completeness and accuracy of information provided as raw material pick lists, interim product kit lists and interim product work content will significantly improve.

8. shop Scheduling. The accuracy of the shop schedules will significantly improve due to "real time" information feedback on efficiency rates, problem areas, and identified bottlenecks.

Impact on Production Activities

1. Material Handling. Material Handling will significantly improve due to several factors:

   o Due to the grouping of products by families, raw material pick lists will be more accurate and timely to support the process lanes. In addition. similar interim products are generally constructed of the same material thus reducing the complexity of the pick list and the picking process.

   o The development of material flow layouts will identify inefficiencies and bottlenecks, and will enhance the material flow.

2. Shop Level-loading. The availability of work content information, and current returns of efficiency rates, coupled with manning projections will enable the planner to level-load the shop to a high degree of accuracy. In addition. shop production management can be made aware of varying manning requirements and respond accordingly.

3. Productivity. The increased accuracy of the schedules, raw material pick lists and kitting lists will improve productivity by having the right material available at the right time. In addition, the construction of similar

interim products in consistent manner will lead to increased productivity through learning curve efficiencies. Also, each step in each process can be analyzed for productivity improvements with changes being incorporated only after the improvements have been verified through simulation techniques.

COMPUTER AIDED PROCESS PLANNING SYSTEM IMPLEMENTATION APPROACH

The implementation of a Computer Aided Process Planning (CAPP) System requires the development of a manufacturing data base which provides interim product/construction process relationships. The prerequisites of such an effort are the identification of similar interim product families and related processes. Once the interim product/process relationships are defined, a consistent approach in applying the processes for producing the interim product must be achieved. When such consistency is achieved, the identification of work content parameters, process constraints and capacity standards can be achieved and the accumulation of data to operate a CAPP system can proceed. A Group Technology (GT) code to facilitate retrieval of the data is, of course, an essential element. As with any project, the procedural steps must be well planned in order for it to be properly managed. Of the utmost importance is ensuring the project has a limited, manageable scope. Encompassing too many processes or too large a production area is a sure step towards failure.

Interim Product/Process Matrix Development

The interim Product/Process matrices presented in the preceding paragraphs are generic in nature and can be used as a first step. It is recommended that the grouping of interim products into families should be reviewed with both production and engineering departments to ensure full acceptance of the matrices. The systematic gathering of the Production Engineering Information proceeds as follows:

- o Detailed Process Descriptions: Methods to accomplish each of the processes should be described including any parameter data that is pertinent to the operation. This data is equivalent to the "feeds and speeds" data in a machine shop. A shipyard’s maintenance shop is frequently a valuable source of data, as is the welding engineer's office. The operator is an excellent source in obtaining opinions on the shop equipments' true capabilities.

- o Detailed Material Descriptions: The primary source for this information is the shop’s material clerk and the shop planner.

  Engineering personnel are also reliable source; however, the list of materials should be reviewed with the shop personnel to delete any unique materials not familiar to the shop. This provides an automatic flag during the planning process to ensure appropriate procedures are invoked to control the fabrication processes.

- o Tooling and Process Constraints: The predominate constraint is often material handling capacity. Capacity information is generally available from a shipyard's industrial engineering office the maintenance office. Work station operators are also an excellent source, especially for safety constraints.

- o Work Content Parameters: Yard budgeters are the primary source for useful parameters. Frequently budgeters will have historical data that they use in formulas for estimating the work content of a task. These formulas and the supporting data can frequently be introduced into the software for the selected CAPP system. The identified parameters should be reviewed with the shop floor supervision because they frequently have easy-to-use methods for determining work content and manning requirements. Being the ultimate user of work content parameter data, the shop floor supervisor should have a major input in its selection.

- o Efficiency Rates: The initial collection of data for developing efficiency rates may be broad based depending on the method of labor return collection used in the shop. The start-up

efficiency rates will generally be Type II labor standards. (the start-up parameter used for the BIW Structural Fabrication shop was linear foot of weld for all assembly processes. The efficiency rate covered all trades, for all processes, from start of assembly to completion of assembly. As the process lanes were developed, the parameter for welders became weld pass length, and for fitters it became fit length or number of pieces.) Once the process lanes become established, Type I labor standards can be determined. Data gathering can then be accomplished for independent steps in the total process. This is probably the first area in which computer assistance is mandatory in order to manage the resulting data base.

- Standard Manning Levels: The establishment of standard manning levels can initially be established based on assembly size. This effort should be coordinated with the shop floor supervisors. The data should be updated after process lane operations have become stabilized.

- Process Lane Capacity: Using efficiency rates and standard manning levels, the throughput capacity for each work station can be determined. This will generally result in one process being a bottleneck for each process lane. These bottlenecks can be analyzed and modifications to each lane implemented to maximize capacity, if production output warrants the changes. If the bottleneck cannot be eliminated, manning for the balance of the process lane must have some flexibility to shift personnel because the bottleneck capacity limits the process lane capacity. In addition, queue storage space for the input and the output of the bottleneck process will generally be required in order to effectively man the balance of the process lane.

Process Lane Development

The start-up of a process lane requires that a number of pre-production activities be established. The following is a list of the essential elements:

- The interim product/construction process matrix to determine which process lanes are required.

- The determination of the parameters to be used to control the manning and scheduling of the process lanes

- The determination of the work content in the interim products to be produced for a period of six to 12 weeks and related Type II efficiency rates to determine which lanes will require some flexibility to construct more than one type of interim product

- Interim product flow networks to determine cycle times and sample manning

- Process lane layout to determine work and storage area requirements. equipment locations and material flow.

The remainder of the tasks are described as follows:

- Work Content Measurement
  Having determined suitable parameters for each of the interim products. the measurement of the work content can be accomplished. For systems such as AUTOKON, numerical control data burn lengths and burn time can be supplied directly from the system. For other interim products, manual determination of the parameter quantity is generally required. This can best be accomplished by a shop planner who is familiar with the general processes that occur in a shop.

- Interim Product Flow Network

  The structural fabrication interim product flow networks for Bath Iron Works were presented earlier in this paper. As is evident, the matrices are an expansion of the interim product/process matrix for each interim product family identified. The interim product flow networks can be developed once the basic interim product/construction processes relationships have been established. Using the work content parameter quantities and preliminary efficiency rates. flow networks can be

used to simulate production runs of typical interim products. This process can identify potential bottlenecks and indicate the areas in the plant layout where buffer storage sites are required. It is helpful to include the preferred manning and the efficiency rates applicable for each process on the network.

- Process Lane Layout

  The material flow. as it presently exists. will provide a valuable tool for determining the layout of actual process flow lanes. Current flow paths that are established due to handling capabilities and space constraints can be identified. The process lane layout can then be developed based on the current flow and the interim product flow networks. It may be necessary to first develop an ideal layout and then develop the best compromise based on a cost/benefit analysis of each suggested rearrangement of equipment and modification of the flow paths.

  It must be recognized that there may be some flexibility required because of interim product quantities as well as changes necessary due to process refinements or improvements. Once the process lane has been put in place, changes should be controlled and implemented only when analysis substantiates that improvement in total productivity will result.

Scheduling Implementation

The shop floor is a dynamic environment susceptible to equipment failures, material problems and manning variations. The schedule must be capable of adequately responding to such conditions. Therefore it is recommended that the shop floor schedule cover only a two week period and that it be updated on a weekly basis. This allows the shop floor supervisor to manage the work at hand and plan for the coming week. This also enables the scheduler to respond to shop floor problems by rescheduling problem jobs downstream and/or developing appropriate work-arounds.

As presented earlier, the actual scheduling process is relatively simple once the work content is known, efficiency rates have been established and station manning levels stabilize.

CONCLUSIONS

The introduction of Computer Aided Process Planning (CAPP) to shipyards brings with it a structured discipline that can result in a significant productivity increase (10-40%) and cost/time savings. The following summarizes the areas where these savings can be realized.

- The recognition of interim product similarities results in a learning curve savings throughout a single ship program.

- The establishment of process lanes to capitalize on interim product similarities results in repeating processes that can be analyzed for process improvement through the use of jigs and fixtures and/or improved technologies.

- The manufacturing data from the "value added" work sites can be monitored using statistical control methods to determine trends in quality, productivity, manning requirements, and the effect of new technologies.

- The raw material and interim product flow paths. which become somewhat fixed because of process consistency, can be determined and analyzed to reduce redundant moves and improve safety.

- The location of equipment relative to raw material and interim product flow can be analyzed to improve productivity and safety.

- The manufacturing processes and sequencing stored in the individual planner’s memories can be captured and stored on hard copy or in a data bank and the best combination of the individual approaches can be utilized in planning work. In addition, the process plans become consistent for similar tasks because the individual preferences are removed from the process plans.

- The process plans contain improved and more complete information. The process plan information can become similar to that provided in machine shops, such as step by step sequence, manning requirements. tool requirements, equipment control parameters, time requirements, kitting informatior, technical data sources, and charging and shipping instructions.

- Consistent data control enhances the application of bar code technology in providing and gathering data. Bar codes for recording charging data. material and interim product identification, kit inventorying, raw material control and material control system input information can be provided on the process plan and kitting documentation to allow for bar code data recording. This can increase data input efficiency by a factor of ten and decrease input error to nearly zero.

- The manufacturing process planner is freed from routine clerical duties and is able to concentrate on methods improvement and cost reduction changes to the process plans.

- The accuracy and consistency of process plans for new projects is improved, which results in a higher confidence level on the part of shop floor supervision and laborers. Budgets and scheduling information are no longer based on "inspired guesstimates", but are based on work content measurement and "real time efficiency rate returns that reflect current methods and capabilities.

- Budgets and schedules can be computer based using work content information and efficiency rates. Thus the budgeter can spend additional effort to determine actual work content and the scheduler can spend his valuable time resolving scheduling problems.

- Data throughout the estimating, design and planning processes become related. Thus, each step in the estimating, program planning, design and detail planning process is a refinement of the data developed during the previous stage. The tiered development of data supports the application of design budgets during the design phase and enhances the capability of a shipyard to develop an auditable trail of the effect of both engineering changes in design and methods and process changes in production.

- Process planning information remains current due to the feedback loops which result from the structured approach required for a CAPP system.

Investigation of CAPP systems revealed a common thread in all systems in that a GT code is necessary to efficiently manage the manufacturing data base. The National Shipbuilding Research Program report "Product Work Classification and Coding", June 1986, presents a useful approach to developing such a code. The investigation also revealed that the code may include many related attributes that may be required for only specific stages in the design/planning/manufacturing process. For instance, the functional attributes necessary for design development and customer approval are not necessary for fabrication and installation but may be necessary for system activation and testing. Thus the identifier carried by a product need only include elements to provide traceability through the manufacturing process. Portions of the code may be added or deleted at each stage. It also became apparent that process related attributes should be added as far downstream in time as data processing/scheduling will allow. Thus, it will be possible to react to the dynamics of shop floor problems and changing production requirements.

The code string expands based on the "first-touch" concept. This means that the first person in the process to logically require or identify a data string adds the related data to the interim product identifier. The computer software then operates only on that portion of the data string required for the process or stage for which the document is being provided.

Review of the commercially available CAPP systems revealed that the systems advertised had a wide range of sophistication from simple word processing manipulation of existing process plans to those that provide all of the recognized outputs in some

form. The more sophisticated systems, such as General Electric Company's CASA/CAMA, tended to rely on other related programs to provide the necessary output, such as a Material Resource Planning System. Whereas others, such as LOCAM had the option of being a unique, stand alone system.

It can be concluded there are commercially available CAPP system that can be applied to the shipbuilding industry without having to develop a unique set of specifications and software. This is due in large part to the generic approach used in the basic, commerical CAPP software. Section 4.7 of the National Shipbuilding Research Program's "Product Work Classification and Coding", June 1986, presents the D-Class approach to a shipyard CAPP system. Appendix E of "Computer Aided Process Planning for Shipyards" August 1986 presents the LOCAM approach. Both approaches capture, in a data base, the manufacturing logic presently contained in the minds and "little black books" of planners and manufacturing engineers. Use of the computer and this decision logic, can now develop consistent, complete, process plans.

The CAPP system is best illustrated in Figure 17.

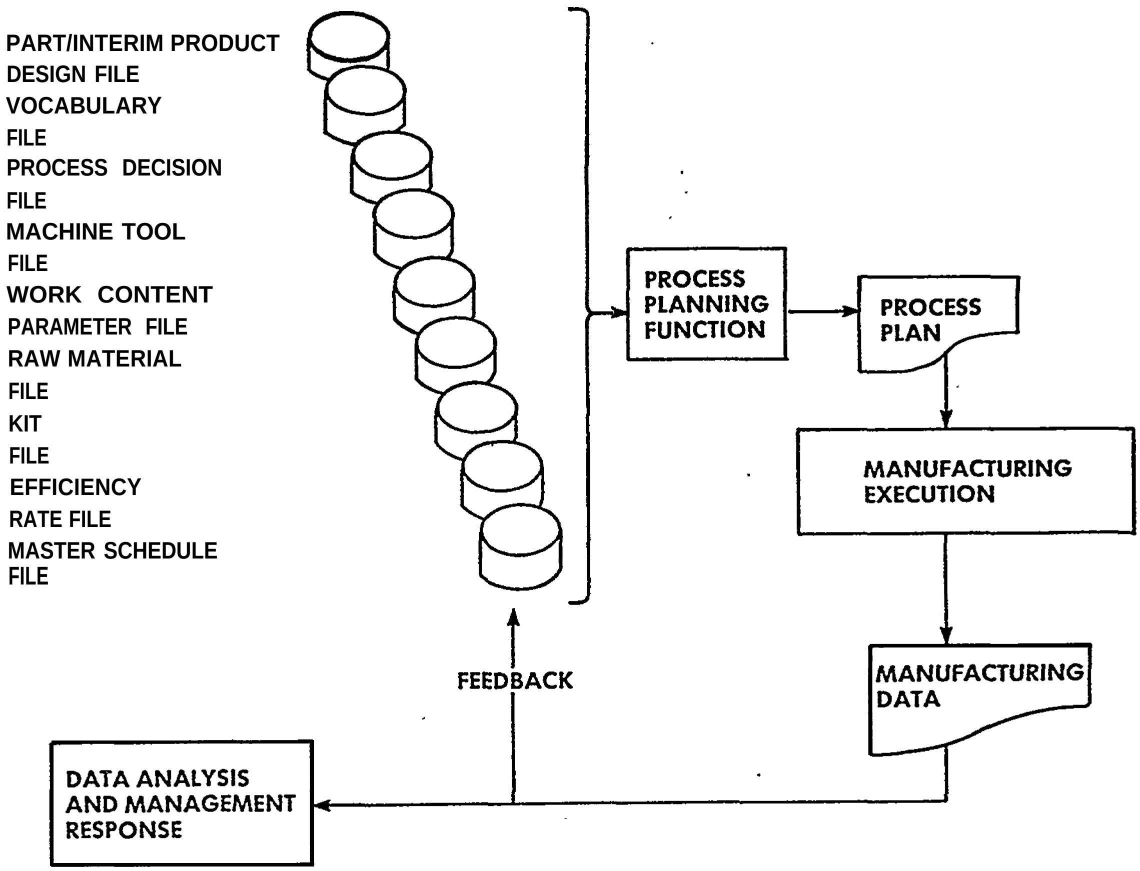

FIG. 17 CAPP SYSTEM OPERATIONS

Design/schedule/manufacturing data **is integrated through the use of** CAPP **system software to develop a** process-plan for each interim product. The results of the process plan are gathered and used to update the data base and to provide information for management action controlling the processes and providing additional feedback to the data base. The approach for each shop is identical with only the data base information changing, based on the parameters required by the interim products.

Recommendations

The development of the structured data base information required for a CAPP system can be very beneficial to a shipyard. Although the actual approach taken by a shipyard for developing such a data base may vary, the basic framework presented earlier should be followed.

It is recommended that the SP-4 panel of the Society of Naval Architects and Marine Engineers fund

a limited implementation project to demonstrate the usefulness of a currently operating CAPP system in the shipyard environment.

The project should include:

o The automated development of Type I time standards for a structural fabrication shop. The "MOST" data developed during the various National Shipbuilding Research Program reports on "Work management" should be used where applicable.

o The generation of GT Codes for a structural fabrication shop.

0 The generation of process plans using a variant process planning system.

o The generation of process planning documents to support process lanes in a structural fabrication shop.

o The publishing of a report documenting the results of the implementation project and a projection of expected savings for the implementation of a CAPP system throughout a shipyard.

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